Journal of Cleaner Production 254 (2020) 120125

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Dietary recommendations in Spain –affordability and environmental sustainability?

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A R T I C L E I N F O

Article history:
Received 10 September 2019
Received in revised form
10 January 2020
Accepted 11 January 2020
Available online 17 January 2020

Handling editor: Cecilia Maria Villas Bôas de Almeida

Keywords:
Carbon footprint
Climate change
Diet
Food waste
Health index
LCA
Sustainable diet
Water footprint

A B S T R A C T

Global food demand is increasing due to population growth and dietary transitions, resulting from rising incomes, are associated with increased prevalence of non-communicable diseases. Improving the sustainability of the food sector is also critical for achieving the Sustainable Development Goals. This study assesses for the first time the greenhouse gases emissions (Carbon Footprint – CF), the water footprint (WF) and the cost of three omnivorous diets recommended in Spain due to their health benefits: the Mediterranean diet (MD), the Southern European Atlantic diet (SEAD) and the Spanish dietary guidelines (NAOS). Analysis was conducted using standard Life Cycle Assessment and WF methods together with current Spanish food price data.

The dietary energy recommendation of the SEAD is greater than that of MD and NAOS (11 and 15% respectively), and SEAD also has greater animal source food content than the other two diets. SEAD has a concomitantly higher CF, WF and cost scores in comparison with MD (+30%, +23% and +21% respectively) and NAOS (+15%, +9% and +21% respectively). Adjusting recommendations to meet the suggested Spanish adult dietary energy of 2228 kcal$\cdot$capita$^{-1}\cdot$day^{-1} changed the environmental profiles of the diets and the NAOS has the highest environmental impact. However, the isocaloric diets had approximately the same cost. Analysis of the WF of the diets identified the major contribution of precipitation (the green WF) to the overall WF (88% of the total) and the significant contribution of animal-source foods to dietary WF. Regardless of the dietary scenario, better scores were identified for the Spanish recommendations analysed than those reported for other healthy diets identified in Europe. Differences in the recommended intake levels of certain food groups, cooking techniques and the origin of food products are behind these results.

Environmental indicators should be considered alongside nutrition and health metrics when defining national dietary guidelines. Supporting citizens to follow healthy and environmentally-friendly dietary recommendations through, among other things, information campaigns and nutritional education programmes is essential.

It is recommended the incorporation not only of health, but also of environmental indicators of these dietary options in the national dietary guidelines, as well as implementation of information campaigns and nutritional education programs among citizens to promote their adhesion since balanced dietary habits rich on plant-based products and low on animal-based ones involve multiple health and environmental benefits.

1. Introduction

Diets intimately link human health and environmental sustainability (Tilman and Clark, 2014).Good nutrition is fundamental to optimal human health; however, over the past decades dietary habits have transitioned towards more processed food, meat,

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https://doi.org/10.1016/j.jclepro.2020.120125

refined sugars and fats, and less fruits, vegetables and whole grains, which contribute to a rise in the incidence of nutrition related non-communicable diseases such as diabetes and coronary heart disease (Willet et al., 2019).The food system components involved in the production and supply of food (crop management, animal rearing, food processing, distribution, cooking practices, waste management, etc.) can have a substantial negative impact on the environment (FAO, 2010), including depletion of natural resources, loss of biodiversity, land use, ecosystem degradation and anthropogenic greenhouse gases (GHG) emissions (Bilali et al., 2019). Agriculture is extremely vulnerable to climate change, as farming activities depend directly on climatic conditions. Growing evidence suggests that environmental change is leading to declines in yields of staple crops and reductions in the quality of both feed crops and forage, threatening to decrease the quantity and quality of food produced (Rojas-Downing et al., 2017). Therefore, scientific evidence addressing improvement of environmental sustainability and resilience of the food sector has accumulated rapidly, aiming to protect future food and nutrition security in light of the expected growth of the world population (United Nations, 2017) as well as anticipated climate change. A sustainable food system should be one that contributes to global food and nutrition security in such a way that the economic, social and environmental pillars to generate this security for future generations are not compromised (HLPE, 2014). Thus, sustainable diets are these consumption patterns and/or dietary choices that are beneficial for human health, nutrition, environmental, social and economic areas (Fischer and Garnett, 2016; World Health Organisation, 2018). Consequently, humanity is facing a huge – but surmountable - challenge to provide the world population with healthy diets from sustainable food systems in the future.

Dietary choice is one of the major leverage points that could make the food system more environmental friendly and resilient. Dietary choice influences the whole food system since it depends on what the consumer eats and how much he/she eats (Hess et al., 2016). Consequently, it impacts on the environment with GHG emission and withdrawal of fresh water among other issues. The former has received special attention in recent years since the food system is responsible for more than 25% of all anthropogenic GHG emissions of which nearly 80% are associated with livestock products (Springmann et al., 2016). The carbon footprint (CF) – measured as kg CO_2eq - has been considered as a proxy indicator of the environmental profile of dietary choices. According to numerous European Life Cycle Assessment studies, consumers' preferred dietary choices considerably affect the country's CF (Saxe et al., 2012; Van Kernebeek et al., 2014; González-García et al., 2018; Van de Kamp et al., 2018; Batlle-Bayer et al., 2019; Esteve-Llorens et al., 2019a, 2019b). Diets low in plant-based products and high in animal-based foods are responsible for the greatest GHG emissions (González-García et al., 2018). In this sense, dietary changes towards lower-meat consumption have been proposed – especially for middle- and high-income settings (Springmann et al., 2016) as well as environmentally friendly strategies such as prioritizing the consumption of non-air-transported products or promoting organic production (Jungbluth et al., 2000; HallströmCarlsson-Kanyama et al., 2015) to reduce dietary GHG emissions. In addition, the introduction of improvement strategies in the food system such as increasing productivity in livestock and feed crops production, developing diets for ruminants in order to reduce enteric fermentation and improving the management of manure would help to reduce the emission of GHG from the food sector (Steinfeld et al., 2006).

The food system also uses large amounts of water; agriculture accounts for around 70% of all freshwater resources (FAO, 2016). Again, dietary choices influence food system water use (Mekonnen and Hoekstra, 2012; Hess et al., 2015). Recent studies have assessed water use in the production of human diets using the water footprint (Vanham, 2013; Vanham et al., 2013a; Harris et al., 2017; Green et al., 2018).

Finally, dietary choices are also directly influenced by the price of foods (Green et al., 2013). Accordingly, food pricing is thus an essential component of the eating setting (French, 2003) with an important implication for people who consume the diets where price is often a major driver in food choice.

Spain has long been associated with two well-known dietary patterns: the Mediterranean diet and the Atlantic diet that are considered two of the healthiest dietary patterns in the world (Calvo-Malvar et al., 2016; Rodríguez-Martín et al., 2019). In past few decades, Spanish dietary habits have shifted towards the so-called "Western diet", characterized by ready-meals and sweets - currently 15% of total energy consumption (Varela-Moreiras et al., 2010; Batlle-Bayer et al., 2019). This transition is associated with increased prevalence of overweight and obesity in the Spanish population, leading to greater incidence of cancer and cardiovascular diseases (Bach-Faig et al., 2006; Ruiz et al., 2015). Furthermore, Westernised diets in Spain are associated with high carbon and water footprints (Blas et al., 2016; González-García et al., 2018).

The Spanish Ministry of Health and Consumer Affairs[1] has developed several strategies to promote healthy dietary patterns for Spanish citizens. Whilst there is a lot of evidence about the health benefits of the more traditional Spanish diets (Mediterranean and Atlantic) as compared to current/Western diets, the environmental footprints and the relative costs of these diets are not well documented. This study aims to quantify the carbon and water footprints of three recommended balanced and healthy diets identified in Spain. The assessment is completed with the estimation of their daily cost (in € per person). Specific attention was paid to the content of the three diets as well as to the production of food waste and losses along the food production chain. Thus, this study tries to identify how these healthy diets meet some of the criteria established by FAO required to define a diet as sustainable (FAO, 2010; World Health Organisation. Information Sheet, 2018).

2. Materials and methods

2.1. Goal of study and functional unit

For the purpose of this study, the three balanced, healthy and omnivorous dietary patterns identified in Spain and promoted by public health agencies, foundations[2,3] and the Spanish Ministry of Health and Consumer Affairs and Social welfare[4] will be analysed from an environmental and economic approach: the widespread and traditional Mediterranean diet (MD), the recently known Southern European Atlantic diet (SEAD) and the dietary pattern following the Spanish dietary guidelines also known as Strategy for Nutrition, Physical Activity and Prevention of Obesity - NAOS in Spanish (NAOS diet). No official data are available concerning the proportions of Spanish citizens consuming the MD, SEAD and NAOS.

The three selected dietary patterns follow the dietary reference intakes based on the frequency (daily, weekly or occasional) with which each food item or category must be consumed (ADF, 2019; MDF, 2019; SENC, 2019). Based on this information for each

[1] https://www.mscbs.gob.es/en/home.htm (accessed June 2019).
[2] https://www.fundaciondiabetes.org/(accessed July 2019).
[3] http://www.fen.org.es/(accessed July 2019).
[4] http://www.aecosan.msssi.gob.es/AECOSAN/web/home/aecosan_inicio.htm (accessed July 2019).

recommended dietary pattern, the estimated daily energy intake (kcal) and the total food consumption (kg) as well as the daily intake of some nutrients were calculated. The results of the assessment are reported using the individual recommended daily dietary intake as functional unit (as basis for analysis). Using this standardisation allowed for comparison between the three dietary patterns and also for further comparison with other published literature (Castañé and Antón, 2017; Corrado et al., 2019; Esteve-Llorens et al., 2019a, 2019b) regardless of daily energy intake.

A sensitivity assessment was conducted adjusting all dietary scenarios to recommended daily energy intake, considering an energy-based functional unit (alternative unit for discussion due to discrepancies in the literature on the best choice of reference unit). The recommended daily energy intake for a Spanish citizen by the Panel on Dietetic Products, Nutrition and Allergies from the European Food Safety Authority (EFSA, 2017) is of 2228 $kcal \cdot person^{-1} \cdot day^{-1}$.

2.2. Dietary patterns definition and design

The characteristics and composition of the three selected dietary recommendations are presented in Table SM1.1 in the Supplementary Material 1 and described below.

2.2.1. Mediterranean diet (MD)

The Mediterranean diet is consumed in several countries including Spain, Italy and Greece (Pairotti et al., 2015). The UN Food and Agricultural Organisation (FAO) has recognized it as an example of a healthy and nutritious diet and a greater adherence to it has been associated with improved health (CIHEAM/FAO, 2015). Adherence to MD is associated with reduction of risk of developing conditions like type 2 diabetes, high blood pressure, high cholesterol and various types of cancers together with reduction of body weight among other diseases, which is supported by the scientific community (Martínez-González et al., 2008; Issa et al., 2011; Vernele et al., 2010). The diet is principally a plant-based diet, rich in fruits, vegetables and nuts and low in animal-based products, with olive oil as the main source of dietary fat (Castañé and Antón, 2017; Sáez-Almendros et al., 2013).

2.2.2. Southern European Atlantic diet (SEAD)

The Southern European Atlantic Diet has been promoted from 2000 in many countries (Esteve-Llorens et al., 2019a) since it is considered a reference for a healthy diet associated with a lower risk of heart attacks among other health benefits involving reductions in total cholesterol and triglycerides as well as lower both obesity indexes and pulse wave velocity values (Calvo-Malvar et al., 2016; Guallar-Castillón et al., 2013; Rodríguez-Martín et al., 2019; Vaz Velho et al., 2016). This dietary pattern is traditional in Northwest Spain and Northern Portugal (Oliveira et al., 2010; Guallar-Castillón et al., 2013). It has several characteristics in common with the MD such as high consumption of vegetables, fruits and olive oil. SEAD is also characterised by high intake of starch-based products (mainly potatoes and bread) and fish and seafood as well as moderate consumption of dairy products and meat (mainly, beef and pork).

2.2.3. Strategy for Nutrition, Physical Activity and the prevention of obesity – NAOS strategy (NAOS)

The Spanish Ministry of Health, Consumer Affairs and Social welfare developed the NAOS strategy to tackle the national rise in obesity rates (Neira and Onis, 2006). In 2011, NAOS was included in Law 17/2011[5] on food safety and nutrition. The strategy promotes food habits in line with the MD but with higher consumption frequencies some foodstuffs such as animal-based and starch-based products among others. A detailed description of these differences can be found in SM2.1 in the Supplementary Material 2 as well as in Table SM1.1 in the Supplementary Material 1. According to the Spanish Observatory of Obesity, adherence to the NAOS strategy reports a reduction in the incidence of obesity among Spanish society that follows the corresponding recommendations (AECOSAN, 2015).

For this study we used serving sizes as defined by the Spanish Society of Community Nutrition (SENC) – see Table SM1.1 in the Supplementary Material 1. However, when specific sizes were identified in the literature for a diet (e.g., in the case of SEAD for starch-based products, vegetables, dairy products, fish, lean meat, nuts, processed meat and sweets), they were considered (Rodríguez-Martín et al., 2019).

2.3. Carbon footprint estimation

2.3.1. Carbon footprint methodology

A Life Cycle Assessment (LCA) approach was followed to determine the GHG emissions associated with each dietary pattern. The CF for each dietary pattern was estimated considering the following three stages with special attention to the production of food waste:

Food production stage (S1) covers production of the different food items that constitute each dietary pattern. This stage follows a cradle to farm or industry gate approach, depending on the specific food group.

Distribution to wholesale and retail stage (S2) includes transport activities involved in the distribution of the different foodstuffs from factory or farm gate to wholesalers and retailers. In this stage, attention is paid to the origin of the different foodstuffs that constitute the designed diets. Although Spain is an important producer of food ingredients such as olive oil, fruits and vegetables (e.g. citrus fruits), it depends on imports of pulses, nuts and some fruit. Therefore, the proportion of food consumed that is nationally produced and imported has been estimated in this study.

Household consumption stage (S3). This stage includes the distribution of foodstuffs from retailers to households. Cooking was excluded from the system boundaries since all the selected dietary patterns recommend similar cooking techniques avoiding complex cooking methods and depend on behavioural factors that are beyond the scope of this study. Thus, the contribution from this activity to the estimation of the CF could be assumed equal in all dietary scenarios. Fig. 1 displays an overview of the life cycle stages considered under study.

2.3.2. Data collection

We included the 44 most frequently consumed foods in the country in our analysis (see Supplementary Material 2-SM2.1) grouped into 11 categories.

In total, 37 LCA studies have been taken into consideration paying attention to the production stage that is, life cycle studies from a cradle to gate (i.e., farm, industry or port) approach since these are the limits established for the production stage (S1). Thus, when cradle-to-grave, cradle-to-retailer or cradle-to-consumer studies were identified, these additional stages from foodstuffs production have been removed from the GHG estimation. A detailed summary of foodstuffs and the GHG emissions identified in the literature are reported in Table SM1.2 in the Supplementary Material 1.

Regarding the distribution from production site to wholesale and retail (S2), the origin of the 44 food items (imports and national production) has been considered following the information

[5] https://www.boe.es/boe/dias/2011/07/06/pdfs/BOE-A-2011-11604.pdf (accessed June 2019).

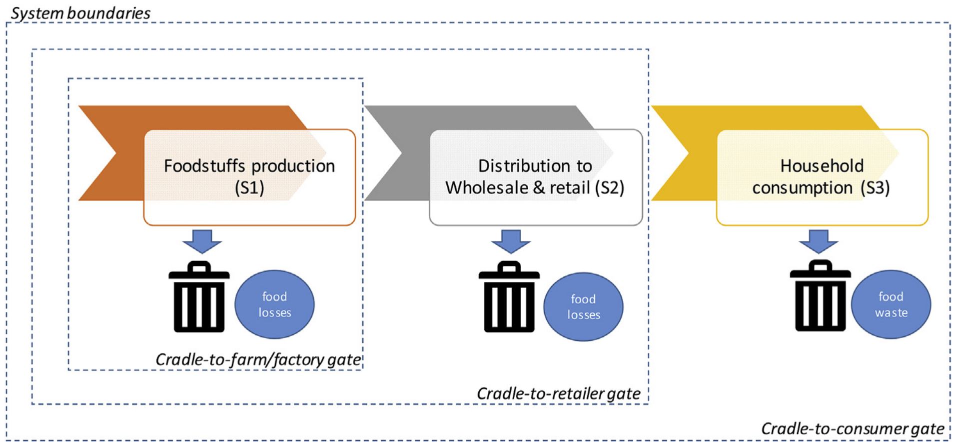


Fig. 1. System boundaries considered in the analysis of the carbon footprint associated to the dietary patterns.

supplied by the Spanish Ministry of Economy and Competitiveness (Ministerio de Economia, 2017).

The national production volume per foodstuff has also been identified in order to define the ratios of consumed food that is nationally produced and imported, required to estimate the final distribution distance per food item. Additional calculations to estimate the average distances, average importing ratios and corresponding methodology is detailed in Table SM1.3 in the Supplementary Material 1 and Supplementary Material 2 – SM2.2.

Finally in S3, it has been assumed that all products that constitute the corresponding food basket per dietary pattern are bought at the same time resulting in a distribution distance of 3.3 km by means of a medium diesel passenger car in agreement with Batlle-Bayer et al. (2019), involving an emission factor of 106 $gCO_2eq \cdot km^{-1}$.

Food losses and waste produced along the supply chain have been computed per foodstuff. According to Garcia-Herrero et al. (2018), food wastage is an environmental and economic problem that needs to be addressed and reduced to contribute to food security. Average percentages of food losses per food category in the retailing stage have been taken from Gustavsson et al. (2013) for Europe since there is not available detailed information for Spain. Regarding the production of food waste at households, the food waste percentages managed per foodstuff are detailed in Table SM1.4 in the Supplementary Material 1. Accordingly, it has been possible to estimate (per recommended dietary pattern) the real amount of foodstuff that should be produced in order to have available the recommended amount of raw food item to be ingested according to the sanitary recommendations. Further description of assumptions and limitations is detailed in Supplementary Material 2 – SM2.2.

2.4. Water footprint description

Water Footprint (WF) is an indicator of freshwater consumption (from rainfall, surface and groundwater) that looks at direct and indirect water use of a producer or consumer and water resources appropriation through pollution (Vanham et al., 2017). The WF accounting described in the Supplementary Material 2 - SM2.3 has been followed to estimate the water footprint associated with the three Spanish dietary patterns selected for analysis based on data taken from Mekonnen and Hoekstra (2011 2012). Given that the dietary scenarios are the sum of 44 individual recommended foodstuffs, the WF for each ingredient has been estimated considering the proportion of consumption that is imported and nationally produced due to the great variability in the water use depending on the origin of food. Information regarding the origin of foodstuff is detailed in Table SM1.3 in the Supplementary Material 1.

There are discrepancies in the literature concerning the inclusion or not of the grey component when the demand of water is being analysed. WFgrey is really a measure of the amount of wastewater produced while WFblue and WFgreen refer to water demand (consumptive WF). Therefore, special attention has been paid to the latter in this study.

2.5. Costing index description

A costing index was developed in order to identify the potential cost of each recommended dietary pattern being expressed in $€ \cdot person^{-1} \cdot day^{-1}$. To do so, the index has been calculated considering the average prices ($€ \cdot kg^{-1}$) supplied by the Spanish Ministry of Agriculture, Food and Environment (MAPA, 2017) which are paid by Spanish inhabitants – on average per foodstuff (see Table SM1.5 in the Supplementary Material 1).The estimation of the costing index, was adjusted for estimated food waste at the consumption stage.

3. Results and discussion

3.1. Composition of dietary patterns

The average daily per capita recommended intake per raw food item for each of the three selected dietary patterns was 2.00 kg, 2.07 kg and 2.30 kg for NAOS, MD and SEAD respectively (Table 1). Factoring in food waste and losses throughout the consumption system increases food requirement by 11% in NAOS and SEAD and, 13% in MD (see Table SM1.4 in Supplementary Material 1). The energy supply estimated per diet is 2240, 2227 and 2675 $kcal \cdot person^{-1} \cdot day^{-1}$ respectively for NAOS, MD and SEAD. The diets differ particularly in their animal source food content (707g, 637g and 410g for SEAD, NAOS and MD respectively; Table 1).

3.2. Carbon footprint assessment and supply chain contributions

The GHG emissions of the dietary patterns were 2.79, 3.15 and 3.62 kg $CO_2eq \cdot person^{-1} \cdot day^{-1}$ for MD, NAOS and SEAD respectively (Table 2 and Fig. 2). GHG emissions from the supply chain were split into three main stages: foodstuffs production (S1), distribution to wholesale and retail (S2) and household consumption (S3). S1 is by far the main contributor to CF covering 85%, 87% and

Table 1
Average daily recommended intake (raw food) per food category for the NAOS Diet -NAOS, Mediterranean Diet-MD and Southern European Atlantic Diet-SEAD; [a] Mostly Brassica genus.

Food group	NAOS ($g \cdot person^{-1} \cdot day^{-1}$)	MD ($g \cdot person^{-1} \cdot day^{-1}$)	SEAD ($g \cdot person^{-1} \cdot day^{-1}$)
Fruits			
Oranges	130.50	152.25	158.55
Apples	72.17	84.20	86.87
Banana	84.77	98.90	88.75
Melon	52.54	61.29	38.11
Watermelon	61.55	71.81	31.36
Mandarine	41.25	48.13	36.10
Pear	37.22	43.43	40.25
Total	**480.00**	**560.00**	**480.00**
Vegetables			
Tomatoes	123.64	247.27	117.10
Onion	67.36	134.72	71.71
Peppers	44.91	89.81	52.77
Lettuce	34.40	68.81	53.92
Carrots	31.22	62.44	36.22
Courgette	33.54	67.07	24.56
Cabbage	14.94	29.87	43.72[a]
Total	**350.00**	**700.00**	**400.00**
Pulses			
Chickpeas	12.02	6.67	10.11
Beans	8.94	6.67	6.93
Lentils	9.04	6.67	7.96
Total	**30.00**	**20.00**	**25.00**
Starch-based products			
Bread	100.00	100.00	262.50
Rice	50.63	67.51	36.76
Pasta	54.37	72.49	53.24
Potatoes	262.50	75.00	300.00
Total	**467.50**	**315.00**	**652.50**
Nuts and olives			
Olives	3.57	27.79	4.29
Almonds	6.88	2.87	5.21
Walnut	7.41	6.84	11.93
Total	**17.86**	**37.50**	**21.43**
Dairy products			
Milk	362.36	133.33	300.00
Yogurt	49.81	103.33	155.00
Cheese	39.70	33.33	50.00
Total	**451.88**	**270.00**	**505.00**
Eggs			
Eggs	**29.00**	**24.86**	**29.00**
Meat			
Lean meat			
Beef	16.07	8.04	18.57
Chicken	24.11	32.14	18.57
Pork	16.07	8.04	27.86
Fat meat			
Processed/Cold meat	7.33	7.86	3.33
Total	**63.58**	**48.21**	**68.33**
Fish and seafood			
Fish			
Hake	18.35	10.49	21.39
Mackerel	1.75	1.00	2.10
Salmon	6.29	3.60	5.22
Pilchard	8.51	3.50	6.45
Cod	6.12	4.86	6.04
Tuna	3.15	1.80	2.51
Seafood			
Prawns	10.43	5.96	9.87
Squids	7.17	4.10	11.31
Mussels	6.99	4.00	9.41
Total	**68.75**	**39.29**	**74.29**
Sweets			
Honey	0.43	0.70	0.48
Sugar	3.57	5.73	6.19
Total	**4.00**	**6.43**	**6.67**
Oils and fats			
Olive oil	**40.00**	**45.00**	**35.00**
Total	**2002.57**	**2074.14**	**2297.21**

Table 2
Summary of carbon footprint, water footprint and costing index of the analysed dietary patterns per functional units considered for analysis.

	NAOS	SEAD	MD
Functional unit based on daily food consumption			
CF (kg CO_2eq·person^{-1}·day^{-1})	3.15	3.62	2.79
WF (L·person^{-1}·day^{-1})	3437	3754	3044
Consumptive WF (L·person^{-1}·day^{-1})	3032	3281	2719
Costing index (€·person^{-1}·day^{-1})	4.06	4.89	4.05
Functional unit based on daily energy intake			
CF (kg CO_2eq·person^{-1}·day^{-1})	3.14	3.01	2.79
WF (L·person^{-1}·day^{-1})	3418	3127	3047
Consumptive WF (L·person^{-1}·day^{-1})	3015	2733	2720
Costing index (€·person^{-1}·day^{-1})	4.04	4.08	4.05

83% of total GHG emissions for NAOS, SEAD and MD respectively. Animal-based products are responsible for 68% of GHG emission for NAOS and SEAD and, 56% for MD (Fig. 2), with dairy products responsible for the greatest emissions (25%–31% of total emissions from S1), followed closely by meat (20%–25%) and fish and seafood (9%–14%) (see Figure SM2.1 in Supplementary Material 2). Fruit and vegetables - categories that constitute 38, 41 and 61% of total daily food intake in SEAD, NAOS and MD contribute 15% (in MD) and ≈9% (in NAOS and SEAD) of total GHG derived from S1 (see Figure SM2.1 in Supplementary Material 2).

Emissions from the remaining supply chain stages (S2 and S3) are similar for the three diets, contributing 15%, 13% and 17% for NAOS, SEAD and MD respectively. S2 including the contributions to the GHG emissions from retailing activities (national and international) contributes 0.11 ± 0.01 kg CO_2eq·person^{-1}·day^{-1} that largely derive from tailpipe emissions from transport activities. S3 emissions are 0.35 kg CO_2eq·person^{-1}·day^{-1} regardless of the diet.

Food loss and waste produced across the supply chain were estimated as 224, 261 and 278 g·person^{-1}·day^{-1} for NAOS, SEAD and MD (82 kg, 95 kg and 101 kg·person^{-1}·year^{-1}). This represents around 6.5% of total GHG emissions associated with food production. The higher intake of plant-based products in MD and their greater perishability compared to animal-sourced foods are behind the largest production of waste in the MD. The production of food waste in households was estimated as 32 kg, 40 kg and 39 kg per capita per year for NAOS, SEAD and MD, respectively.

3.3. Water footprint assessment

The water footprints of the three diets ranged from 3045L to 3754L per capita and day (Table 2). WFgreen represents by far the largest fraction regardless of the diet (Fig. 3a) and differed between the three diets: 2516L, 2753L and 2194L per capita and day for NAOS, SEAD and MD. The dietary patterns more dependent on animal-based products and specifically on meat (NAOS and SEAD) had higher WFgreen than MD, which is more reliant on products of vegetable origin. Fig. 3b shows the WFgreen sorted per food categories according to quantities required per dietary pattern. Animal-based products account for 50% of WFgreen in NAOS and SEAD and 38% in MD.

Dairy products have the highest contribution to WFgreen in NAOS and SEAD followed by the oils & fats category that includes olive oil. This is opposite in MD, where oils & fats category is the largest contributor. Although olive oil does not represent a main foodstuff in the three dietary patterns in terms of grams consumed per day, its effect on the WFgreen is considerable. Olive oil, the staple source of fats in the three diets, is one of the foodstuffs with the highest WFgreen associated per tonne (10.6 m^3 t^{-1}) behind almonds (26.2 m^3 t^{-1}) and beef meat (11.4 m^3 t^{-1}). Differences between diets in WFblue are small (approx. 10–12L per capita and day).

3.4. Costing index assessment

The cost of the MD and NAOS diets were similar but the SEAD diet was 1.21 times more expensive (Table 2). Animal-based products represent ≈40% of food expenses in NAOS and SEAD scenarios and 31% in MD. In all of them, dairy products are behind the highest contribution derived from animal-based ones specifically in SEAD (Figure SM2.2 in Supplementary Material S2). In MD, expenditure on vegetables represents the highest contribution to the daily cost (27%) followed by fruits (18%) and starch-based

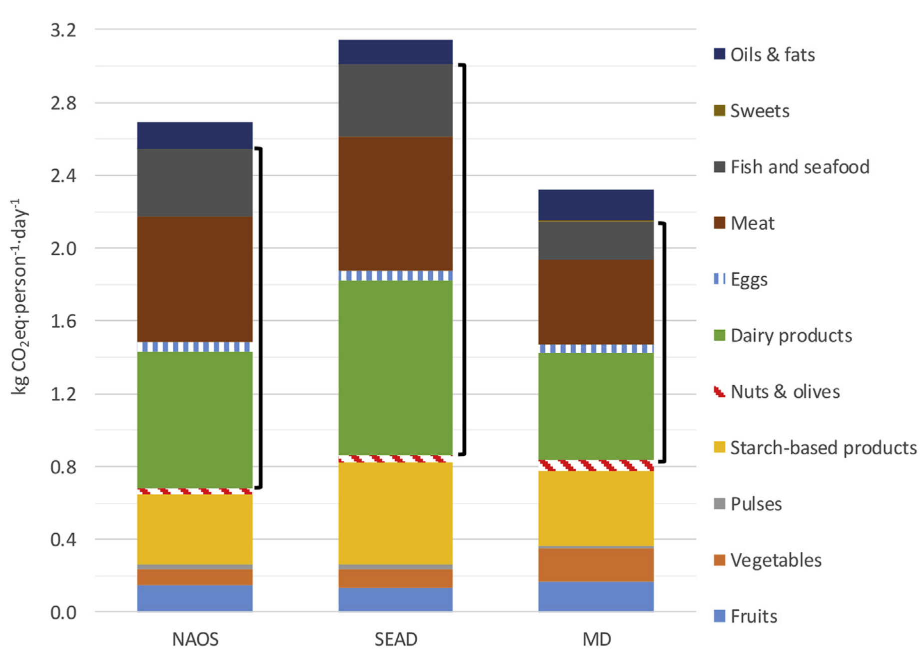


Fig. 2. Distribution of GHG emissions between food categories per dietary pattern analysed. The black key identifies the animal-based products.

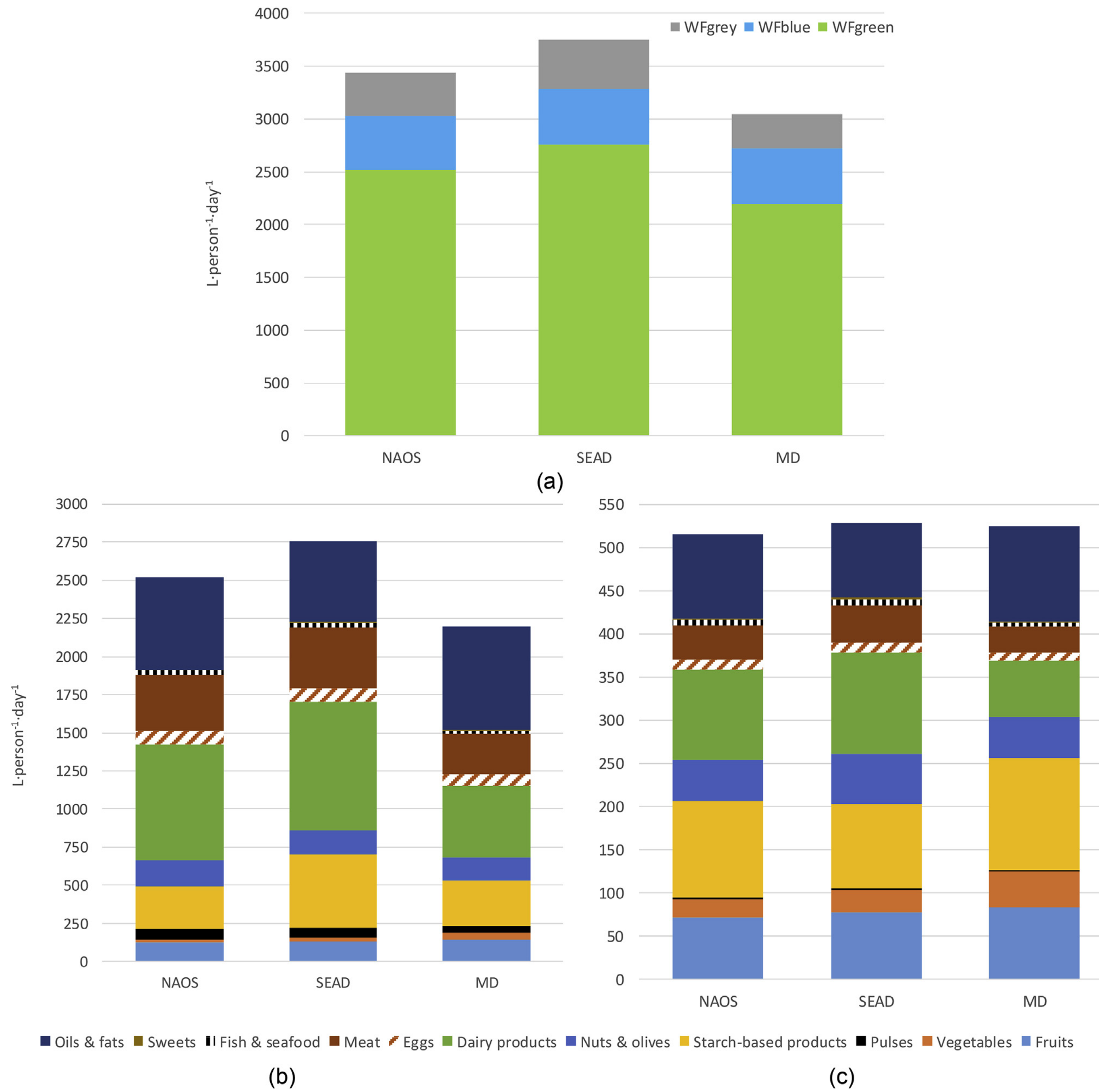


Fig. 3. a) Water Footprint (WF) estimation (L·person^{-1}·day^{-1}) per component and dietary pattern; Distribution (in L·person^{-1}·day^{-1}) of WFgreen (b) and WFblue (c) between food categories and dietary scenario.

products (15%). In NAOS and SEAD the distribution is close similar with starch-based products contributing to 21% and 27% (respectively) of total daily food expenses, followed by dairy products (16% and 18%) and, fruits and vegetables (28% and 26%).

4. Discussion of results

The three recommended "healthy" diets in Spain show different caloric intakes with SEAD substantially above the recommended calorie intake. Regarding CF, they also vary greatly in terms of GHG emissions, with MD the best and SEAD the worst being most of the emissions produced in the foodstuffs production stage. SEAD also reports the highest WF (up to 23% and 10% higher than MD and NAOS, respectively) being olive oil the food product with the biggest footprint in MD and, dairy products in NAOS and SEAD. Hence there are some trade-offs in each recommendation related to health and environment.

4.1. Carbon footprints

Our results corresponding to the CF for NAOS, SEAD and MD are in line with those identified in the literature based on the daily amount of food consumed per capita. However, there are differences mostly linked to different data sources and assumptions established by the authors. Castañé and Antón (2017) assessed the Mediterranean diet by designing daily menus and identified an average CF of 2.14 kgCO_2·person^{-1}·day^{-1}. The exclusion of food waste production, assumptions on retailing and different consulted sources can be the rationale behind that lower score in comparison with our value. Esteve-Llorens et al. (2019b) reported 4.53 $kgCO_2 \cdot person^{-1} \cdot day^{-1}$ for the Atlantic diet, including food waste production. This study was also based on the design of weekly menus. The authors considered the daily intake of 2.75 kg food per capita (20% higher than other estimation). According to that study, 90% of GHG emission are associated to food production stage (4.08 $kgCO_2 \cdot person^{-1} \cdot day^{-1}$). This value is 30% higher than the one obtained in our estimations (3.15 $kgCO_2 \cdot person^{-1} \cdot day^{-1}$). A higher intake of fruit (2 times), vegetables (1.6 times), meat (1.3 times) and fish (2.6 times) than in our scenario is behind these remarkable differences. Finally, Battle-Bayer et al. (2019) analysed Spanish dietary guidelines, estimating 2.44 kg food ingested per capita and day and reporting a CF of 3.08 $kgCO_2 \cdot person^{-1} \cdot day^{-1}$, close to our score for NAOS. Differences on assumptions not only regarding data sources but also concerning recommended servings and system boundaries (cooking was included) are behind the variation on the CF score.

4.2. Water footprints

Our results concerning the WFs for the three diets (3044L, 3437L and 3754L per capita and day for MD, NAOS and SEAD) are in line with the ones reported by Vanham et al. (2013) for a healthy diet based on German recommendations (3291$L \cdot person^{-1} \cdot day^{-1}$) and by Vahnam et al. (2013b) for a vegetarian diet in Southern European countries (3476$L \cdot person^{-1} \cdot day^{-1}$) – where fruits and vegetables are cultivated under irrigation, and healthy diets in Northern and Eastern European countries (3091$L \cdot person^{-1} \cdot day^{-1}$ and 3606$L \cdot person^{-1} \cdot day^{-1}$, respectively). However, the scores are considerably lower than the one reported by Vahnam et al. (2013b) for a healthy diet in Southern European countries (4110$L \cdot person^{-1} \cdot day^{-1}$). Bearing in mind these results it is possible to point out the outstanding differences between countries and regions considering the intake of different food categories despite following sanitary recommendations. Specifically, for healthy diets, they were based on very different nutritional guidelines (Scandinavian, German and Mediterranean) which are considerably different for several reasons (climate, traditions and lifestyles). In this sense, recommendations concerning meat intake are Northern European countries than in Mediterranean and Eastern ones (Vahnam et al., 2013b). Additionally, it is important to understand the food production processes in terms of water use. The type of product, (plant or animal based), the origin-country and its climatological conditions can all considerably affect the water used in production. In this sense, Vahnam et al. (2013b) highlight that countries located in Southern Europe due to their higher temperatures and lower rainfall, report greater evapotranspiration of the plants and more WFs (specifically WFblue) per tonne of certain products that countries located in Northern Europe.

The result obtained in our study for the MD in WFgreen (2194 $L \cdot person^{-1} \cdot day^{-1}$) and in global WF (3044 $L \cdot person^{-1} \cdot day^{-1}$) are around 20% and 25% higher respectively than the ones reported by Blas et al. (2019) for this dietary pattern. These differences are related to methodological factors. Blas et al. (2019) designed a Mediterranean scenario based on food consumption levels at household in the period 2014–2015. Thus, the assessment only accounted for food intake in the household excluding consumption out-of-home (according to the authors, the latter could represent 25%). They applied modelling assumptions to account for this, which may have underestimated the actual food intake. In addition, production of food waste at households and delivery was not included in the analysis, which should increase the food consumption flows and thus, the associated WF. Moreover, no WF indicators were considered for fish and seafood by Blas et al. (2019). On the contrary, data from Pahlow et al. (2015) were used in our analysis to estimate WF associated with aquaculture production of fish.

4.3. Costing indexes

Concerning the costing index, regardless of the dietary pattern, the results identified in this study are below the ones reported by Germani (2014) for an Italian consumer with a Mediterranean dietary habit even not considering the production of food waste at household. According to Germani (2014), the cost is 5.33€$\cdot person^{-1} \cdot day^{-1}$. The rationale behind this difference is mainly associated with the data source used to estimate prices per foodstuffs (i.e., different country) and the reference year (2013 vs 2017).

4.4. Food waste

Food waste rates produced at home were estimated considering average flows of food consumption and food waste production in Spain as detailed in Supplementary Material 2 – SM2.2. The rates identified in our study regardless the scenario (37 ± 3.6 $kg \cdot person^{-1} \cdot year^{-1}$) are in line with the one (32 $kg \cdot person^{-1} \cdot year^{-1}$) reported by the Spanish Ministry of Health (HISPACOOP, 2012) obtained from weekly surveys in Spanish households and slightly below those (49 $kg \cdot person^{-1} \cdot year^{-1}$) estimated by EUROSTAT (Monier et al., 2011) for Spain and the average for EU27 (49 $kg \cdot person^{-1} \cdot year^{-1}$). The rationale behind these differences could be associated with the data source, the procedure to collect the information regarding the amount of waste produced and the considered method to define the concept of food waste.

4.5. Sensitivity analysis

In our study, the functional unit as basis for analysis was founded on the total daily amount of food recommended to be ingested per capita, complying with the recommended nutrient intake according to the guidelines for each dietary pattern. The corresponding energy intakes were 2240, 2675 and 2227 $kcal \cdot person^{-1} \cdot day^{-1}$ for NAOS, SEAD and MD, respectively. These values are in line with those found in the literature for designed diets following the considered sanitary recommendations (Agnoli et al., 2018; Medrano et al., 2012; Widner et al., 2014). Despite the huge differences in energy content, all of them are linked to health benefits. Other healthy diets reported in the literature for European countries (Vanham et al., 2013a, 2013b) supply daily energy contents ranging from 2200 kcal to 2450 kcal per capita. Therefore, when comparison among studies is addressed, the energy supply could be a key issue. Based on this approach, the dietary scenarios have been readjusted to the recommended energy intake for a Spanish citizen (2228 $kcal \cdot person^{-1} \cdot day^{-1}$) and compared with literature. Nevertheless, the readjustment does not guarantee the required daily nutrients. Table 2 shows the CF, WF and cost index for the three readjusted dietary scenarios. Bearing in mind these results, outstanding differences can be identified shifting the reference unit.

4.5.1. Carbon footprints

The comparison in terms of GHG emission has been performed considering, when possible, the same system boundaries, although differences concerning data quality and sources cannot be avoided and could affect the results. Moreover, some studies have not included all the stages in the analysis such as food waste and food losses production all over the food chain which underestimates the results. Six studies available in the literature have been included in the comparison deriving into seven scenarios: the Mediterranean diets reported by Castañé and Antón (2017), Ulaszewska et al. (2017), Germani (2014) and Sáez-Almendros et al. (2013), the balanced omnivorous diet from Corrado et al. (2019), the Southern European Atlantic diet from Esteve-Llorens et al. (2019b) and the New Nordic diet from Ulaszewska et al. (2017). Table SM2.2 in the Supplementary Material 2 details the CF and corresponding system boundaries for the diets considered for comparison.

The choice of considering these studies based on balanced diets instead of current dietary patterns is because the main goal of diets is to provide the nutrients required for life and real consumption trends cannot meet that goal (Batlle-Bayer et al., 2019; Esteve-Llorens et al., 2019b, 2020). The results achieved in our scenarios must assessed with care but in general they are in line with those identified in the literature although some differences can be highlighted which can be linked to data quality, the use of different data sources, the country and assumptions established (e.g., assumption of distribution distances). In our studies, the origin of all foodstuffs included in the diets was assessed in detail and thus, the corresponding travel distances.

In other studies, such as Castañé and Antón (2017) and Esteve-Llorens et al. (2019b), average distances were considered, which underestimate the GHG emissions. Regardless the study, the majority of GHG emissions occur in the foodstuffs production stage. However, stages after the food production (e.g., distribution and food waste) should be considered when estimating GHG emissions from dietary patterns.

If a cradle-to-retail approach (excluding food waste production) is considered for comparison, the CF for the MD (2.35 $kgCO_2 \cdot person^{-1} \cdot day^{-1}$) is in line with those identified by Germani (2014) and Sáez-Almendros et al. (2013). If food waste production is included, the score obtained for SEAD (2.72 $kgCO_2 \cdot person^{-1} \cdot day^{-1}$) is considerably far from the one (3.94 $kgCO_2 \cdot person^{-1} \cdot day^{-1}$) reported by Esteve-Llorens et al. (2019b). The same occurs if distribution to consumer is also included (3.01 vs 4.81 $kgCO_2 \cdot person^{-1} \cdot day^{-1}$, respectively). The rationale behind these differences is associated with different data sources used to both determine the CF per foodstuff (e.g., 28.60 $kgCO_2 \cdot kg^{-1}$ of beef meat were considered in Esteve-Llorens et al. (2019b) vs 24.69 $kgCO_2 \cdot kg^{-1}$ in our study) and to design the dietary pattern (e.g., 2.92 kg of food$\cdot person^{-1} \cdot day^{-1}$ in Esteve-Llorens et al. (2019b) while in our study it is 1.91$\cdot person^{-1} \cdot day^{-1}$ for 2228 kcal).

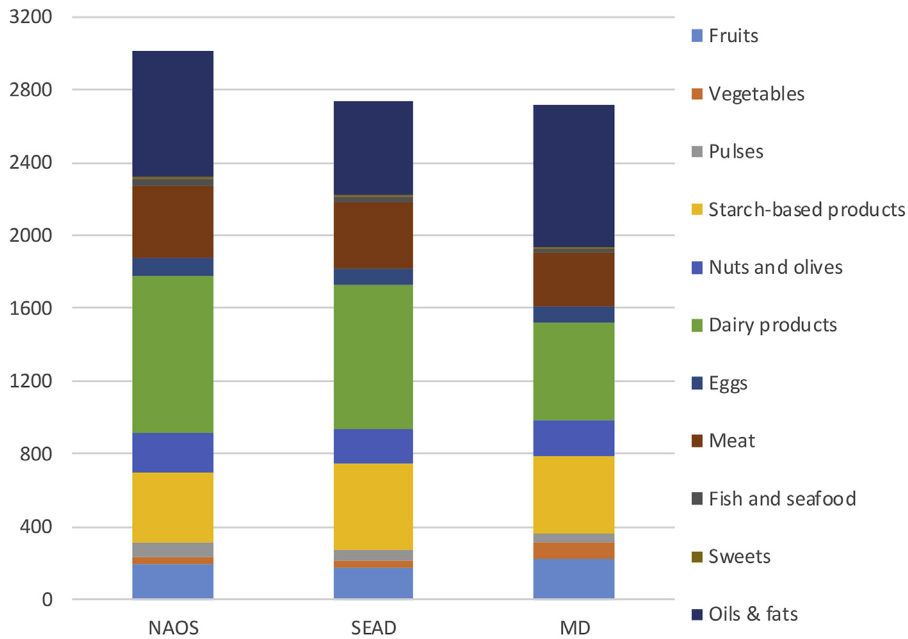
If the scores for NAOS, SEAD and MD – all of them omnivorous dietary patters, are compared with the balanced omnivorous diet reported by Corrado et al. (2019), they are between 25% and 33% lower considering the same approach (cradle-to-consumer, excluding cooking and including food waste production). The latter study follows the Italian dietary recommendations and different portions and weights were identified in comparison with the Spanish ones (e.g., in terms of dairy products). These issues together with different data sources are behind the variations.

Finally, the comparison has been performed with the New Nordic diet -NND (Ulaszewska et al., 2017), which is an omnivorous diet that promotes locally produced and organic food as well as with some similitudes with SEAD and NAOS such as the high intake of potatoes, fish and seafood. However, and as difference to SEAD, this dietary pattern follows the Nordic nutritional recommendations (Ulaszewska et al., 2017) which differ from the Spanish ones (e.g., regarding the consumption of rice, pasta, bread or fats). The score reported by Ulaszewska et al. (2017) includes cooking stage without identifying its effect over the CF but excluding food waste production from the system boundaries. Bearing in mid this approach and considering that in an omnivorous diet around 0.53 $kgCO_2 \cdot person^{-1} \cdot day^{-1}$ are associated to the cooking stage (Corrado et al., 2019), the CF score associated to NAOS (3.49 $kgCO_2 \cdot person^{-1} \cdot day^{-1}$) should be close to the NND (3.88 $kgCO_2 \cdot person^{-1} \cdot day^{-1}$). On the contrary, the scores should be 15% and 18% lower for SEAD, and MD. Different data sources and amount of ingested food are behind the differences in GHG emissions.

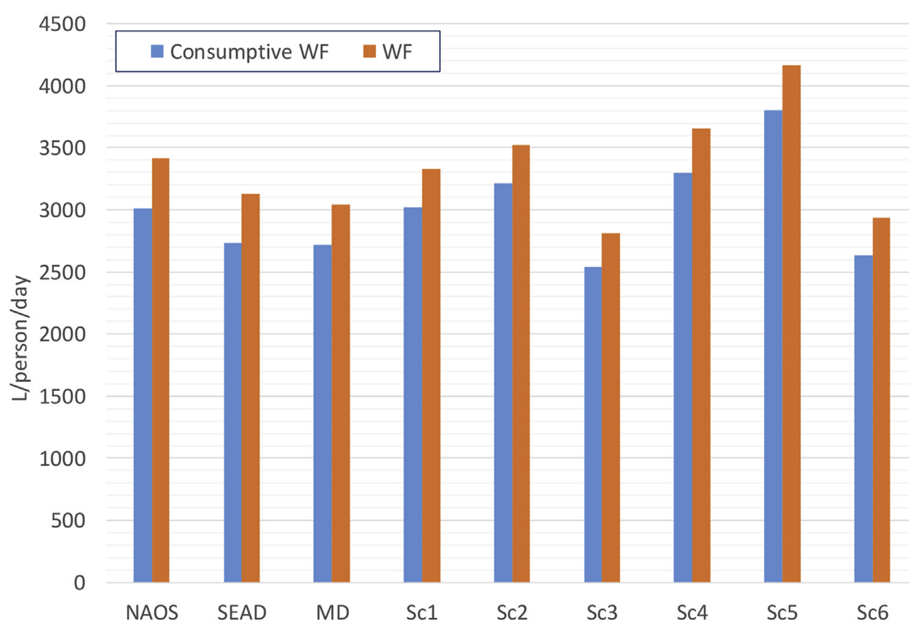
4.5.2. Water footprints

Readjusting the three scenarios to the same energy intake, NAOS diet reports higher WF (3418 $L \cdot person^{-1} \cdot day^{-1}$) and consumptive WF (3015 $L \cdot person^{-1} \cdot day^{-1}$) in comparison with SEAD and MD, which both present similar values (3127 and 2733 $L \cdot person^{-1} \cdot day^{-1}$ and, 3047 and 2720 $L \cdot person^{-1} \cdot day^{-1}$,respectively). Thus, the distribution of food intake suggested by NAOS diet reports a higher WF per kcal than the other dietary scenarios despite SEAD involving a slightly higher dependence on animal-origin foodstuffs (10% lower global and consumptive WFs). Nevertheless, SEAD and MD have practically the same WFs despite the outstanding differences being the latter a dietary pattern based on plant-based foodstuffs (1.40 and 1.37 L/kcal of global WF and, 1.23 and 1.22 L/kcal of consumptive WF, respectively for SEAD and MD). SEAD is benefited by making the energy readjustment involving a reduction in food intake (2.13 $kg \cdot person^{-1} \cdot day^{-1}$). Differences in WF per kcal can be attributed not only to different food consumption intakes (animal-based vs plant-based foodstuffs) but also to the variation in the WF because of the origin of products consumed. The origin of foodstuffs affects the consumption of blue and green WF as well as the production yield and production regime. In this study, all dietary scenarios are constituted by the same foodstuffs (thus, they have the same precedence regardless the dietary pattern) although distributed in a different way. Therefore, and according to Table SM1.4 and Table SM1.6 in Supplementary Material 1, diets rich in nuts (mainly almonds and walnuts), pulses (chickpeas and lentils), olive oil and cereals (rice and pasta) can derive into high WFs since these products have associated high green and blue water footprints being in some cases even higher than the ones for meat. In this case, the major intake of olive oil in the MD is the rationale behind the higher WF associated to MD in comparison with SEAD (see Fig. 4a). Bearing in mind our results, diets with a high proportion of vegetables and fruits should derive into low water requirements. The results for the global and consumptive WFs reported by Vanham et al. (2013) and Vahnam et al. (2013b) have been considered for comparison readjusting all the diets to 2228 kcal$\cdot person^{-1} \cdot day^{-1}$. In addition, the result from Blas et al. (2019) for their designed Mediterranean diet based on current consumption trends by Spanish citizens has been considered in the analysis but including the 25% of food consumed out-of-home. However, attention should be paid to the fact that in that study the values of food waste produced in the home have not been subtracted, so data do not represent the final food intake. In addition, the study does not include the waste of food produced in the retail stage, which may be relevant as indicated above and considers the consumption of beverages.

Comparing our scenarios with those identified in the literature (see Fig. 4b), NAOS should in line with the German healthy diet – Sc1 reported by Vanham et al. (2013) which results from the Swiss nutritional pyramid and reports a lower daily consumption of fruits, vegetables and dairy but a higher intake of animal fat and sugar. However, attention should be paid to the fact that these authors substituted the amounts of fish recommended (c.a. 80 g per week) by meat and in our study the WF has been only identified for these fish products from aquaculture (salmon, cod and prawns, which all together represent 28–33% of total fish and seafood). The results achieved for the three diets analysed in our study are far from the ones estimated for the vegetarian diet in Southern Europe countries (Sc2) and the healthy diets for Eastern and Southern Europe countries –Sc4 and Sc5 (Vahnam et al., 2013b), which report 1.46, 1.50 and 1.73 L of consumptive WF per kcal (3520, 3652 and 4162 $L \cdot person^{-1} \cdot day^{-1}$, respectively for WF). According to the



(a)



(b)

Fig. 4. (a) Distribution of combined green and blue WF between food groups per dietary pattern readjusted to 2228 kcal·person^{-1}·day^{-1}; b) WF and consumptive WF for the different scenarios selected for comparison. Sc1 from Vanham et al. (2013), Sc2-Sc3-Sc4-Sc5 from Vahnam et al. (2013b) and Sc6 from Blas et al. (2019). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

authors, the mentioned healthy diets are in line with the German and Mediterranean recommendations. Differences in the results could be associated with the origin of food imported which considerably varies between countries. Regarding the vegetarian, the high WF associated should be linked to the substitution of all meat by pulses, nuts, oilcrops and soybeans which have WFs in line with animal-based products.

The WFs for SEAD and MD are close to those reported by Blas et al. (2019) – Sc6 despite the differences in the system boundaries. However, a slightly higher WF is expected for the scenario corresponding to Blas et al. (2019) if the same system boundaries were established.

Finally, the healthy diet corresponding to Northern countries -Sc3 (Vahnam et al., 2013b) reports lower WFs than those for our dietary patterns. It is a diet rich on animal-based products even higher than those corresponding to NAOS and SEAD. The rationale behind the lower value could be associated to the estimated amounts of food waste per food category which differ between studies because of the use of different data sources.

4.5.3. Costing indexes

Regarding the costing index, the scores readjusting the scenarios to 2228 kcal per person and day are 4.04€, 4.08€ and 4.05€ per capita and day. Germani (2014) assessed the cost of Mediterranean diet and readjusting to the same energy intake, the corresponding index should be 5.94€·person^{-1}·day^{-1}. Differences on market prices for the foodstuffs between Spain and Italy are behind these variations although in Germani (2014) it was not computed the costs associated to food waste production.

Jones et al. (2014) determined the costs associated with more and less healthy diets considering UK consumer prices. According to that study and readjusting the scores to 2228 kcal, costing index of 6.18€ should correspond to an unhealthy dietary pattern. This score is higher than those identified for the three dietary scenarios under study. Although discrepancies exist regarding market prices between UK and Spain, the finding could give an idea regarding the promotion of the adherence to healthy diets in Spain.

4.6. Further recommendations

Spanish dietary guidelines (NAOS strategy) together with both Southern European Atlantic and Mediterranean diets aim to provide healthy dietary choices to Spanish citizens. Although their health benefits are well-known between health community, the adherence of the society to these dietary choices is far from desirable deriving into higher intake of animal-based products and lower consumption of plant-based ones and consequently, involving negative environmental issues. Human choices have effects not only related with health. Environmental consequences derived from food choices such as climate change and water resources scarcity should not be left aside. Specifically, in the case of Spain, a country which is suffering extreme weather events and intense droughts and where global warming is threating crops and water resources (Hervás-Gámez and Delgado-Ramos, 2019). Thus, for an environmentally sustainable future and looking at the Spanish Sustainable Development Strategy (Spanish Government, 2018), attention must be paid to human diets and quite radical change to our dietary choices is needed in order to achieve food security and promote sustainable consumption patterns. One of the pressures is that developing Spanish citizens are shifting to an animal-based diet moving away from sanitary recommendations. Spain in one of the European countries in which more meat per person is consumed per year, occupying the second position in the ranking after Austria (Meat Price Index, 2017). Eat smaller animal-based products portions, even fewer times per week, or substituting them by alternative plant-based ones could be a measure to minimize environmental and even health problems (Godfray et al., 2018). In addition, consumers should be informed of environmental consequences linked to the miles that their food has had to travel. In this sense, locally sourced and seasonal food is good for both the health and the environment, and consumption of that food is encouraged by Mediterranean and Atlantic diets (Esteve-Llorens et al., 2019a).

Accordingly, campaigns should be made to make consumers aware of what they are eating (and where their food comes) and the consequences of that. Therefore, public health activities should be established and promoted in order to disseminate them between consumers. The design of intervention activities to disseminate between families and/or consumers the environmental consequences derived from their food behaviours could be considered. Thus, short-lived nutritional and environmental education activities should be conducted, providing information regarding nutritional recommendations, recipes together with menu planning and culinary advice.

In addition, attention should be paid to other issues such as their associated environmental benefits (environmental cost is totally different between beef meat and alternatives such as pork and chicken). Thus, it is recommendable to incorporate environmental indicators (such as carbon and water footprints) within the guidelines in order to provide additional valuable information to consumers. Moreover, and with the aim to inform the population about the positive effects on health and environment of these balanced diets, it should be necessary to perform training and dissemination activities at different levels of society: schools, families and business (food and drink industry, catering trades). Information campaigns, nutritional education programs (promoting the consumption of fruits and vegetables in schools to combat problems such as childhood obesity and other healthy living habits such as physical exercise) and enhancing the collaboration with food companies are examples of strategies that should be performed.

Another relevant issue related with dietary choices is the cost. Therefore, economic decisions affect food choice. Numerous studies report that energy-dense, nutrient-poor foods[6] and consequently energy-dense diets have a lower satiating effect deriving into weight gain. Drewnowski and Darmon (2005) reported that the low-cost energy-dense diets also tend to be nutrient poor. In a recent study (Jones et al., 2014), it was demonstrated that healthy food is more expensive than less one (up to 3 times higher). According to our results and bearing in mind the ones from Jones et al. (2014), the choice of any of the proposed dietary patterns would not have an economic implication, being even lower than reported cost for unhealthy diets. However, current food strategies to promote sustainable food consumption need to be revised e.g., limiting access to inexpensive and energy-dense, nutrient-poor foods through taxes on frowned upon fats and sweets (Lee et al., 2018; Roberto and Khandpur, 2014).

The findings from this study identify that the proposed diets are well positioned in the sustainability domains considered for assessment in comparison with other dietary patterns. Nevertheless, questions remain regarding other issues that should be considered in order to obtain a full-overview of a healthy diet sustainable produced. In this sense, loss of biodiversity, deforestation, social concerns and policy options are aspects that require an exhaustive analysis to promote sustainable diets.

5. Conclusions

Although the Mediterranean diet is the most widespread and recognized worldwide, there are other healthy omnivorous dietary choices promoted in Spain with benefits not only for health but also for the environment and whose adherence should be promoted. The present study evaluates the three balanced dietary patterns recommended by different Spanish health agencies due to their potential health benefits. The assessment has been performed in terms of three indicators: carbon footprint, water footprint and costing index. Conclusions are sensitive to assumptions and data

[6] Energy-dense, nutrient-poor (EDNP) foods are those containing fats, oils and sugars, presenting a marginal micronutrients content (such as vitamins and minerals) and too many calories; these foods constitute the tip of the food guide pyramid (Kant, 2000). Examples are: savory sauces, confectionary, pastries and batter-based products.

quality. In addition, attention should be paid to the definition of an appropriate functional unit to report the results since opposite conclusions are got if a mass-based or energy-based unit is considered. Diets should provide both the energy and nutrients required daily and this aspect should be guaranteed when comparing different dietary options.

The results from this study corroborate the relevance of the contribution from dietary choices to climate change giving insights regarding which foodstuffs have a major effect on greenhouse gases emission. Differences ranging from 14% to 30% on GHG emission have been identified between the three scenarios, being SEAD the one that reported the worst score when a mass-based unit is considered. Regardless the reference unit, MD reports the lowest carbon footprint because its higher dependence on plant-based products. However, attention should be paid to data sources since considerably affect the results and could result in opposite conclusions.

Concerning the WF, MD achieves the lowest score in WF regardless the reference unit. SEAD and NAOS present the second-best scores when energy-based and mass-based units are considered, respectively. One relevant limitation regarding this parameter is the lack of information for non-aquaculture fish and seafood which underestimates the results. Green (rainfall) water accounts for most of the water consumed in the production of diets globally (around 88% of total). Differences in blue water between dietary patterns are almost negligible. Hence, changes in agricultural production should be considered. Improving crop irrigation techniques such as moving from a full to a deficit irrigation strategy or shifting from sprinkler or furrow irrigation to subsurface drip irrigation as well as introducing the use of organic mulching practice should considerably reduce the demand of water requirements without large cost increases (Chukalla et al., 2017).

In terms of cost, the expense is similar for NAOS and MD although slightly higher for SEAD when a mass-based unit is considered, mainly because of the higher intake of food recommended per capita and day. On the contrary, NAOS should involve a higher costing index when diets are readjusting to the recommended energy intake, getting MD and SEAD equal scores.

Bearing in mind the global results, NAOS and SEAD can be considered alternative dietary choices to MD with environmental and health benefits. Public campaigns should be developed to promote both dietary patterns between the Spanish citizens.

Author contribution

S.G.-G. conceived the presented study, designed the scenarios, analysed and acquired the main data, performed the measurements and led the writing of the article. R.F.G., P.F.S., F.H. and A.D.D. made substantial contributions to conception and design, analysis and interpretation of data. R.F.G., P.F.S., F.H. and A.D.D. participated in drafting and revising the article. A.D.D. supervised the work in detail. S.G.-G., R.F.G., P.F.S., F.H. and A.D.D. gave final approval of the version to be submitted and any revised version.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This research has been partially supported by a project granted by Xunta de Galicia (project ref. ED431F 2016/001) and by the Spanish National Research Agency (project ref. CTQ2016-75136-P). S.G-G. would like to express her gratitude to the Spanish Ministry of Economy and Competitiveness for financial support (Grant reference RYC-2014-14984). S.G-G. belongs to the Galician Competitive Research Group GRC 2013−032 and to CRETUS Strategic Partnership (AGRUP2015/02). All these programmes are co-funded by Xunta de Galicia and FEDER (EU).

R.F.G., P.F.D.S., F.H. and A.D.D. are part of the Sustainable and Healthy Food Systems (SHEFS) programme supported by the Welcome Trust's Our Planet, Our Health programme (grant number: 205200/Z/16/Z). S.G-G. gives thanks RYC-2014-14984 for financing the research stay in the London School of Hygiene & Tropical Medicine where this study was entirely developed.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2020.120125.

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